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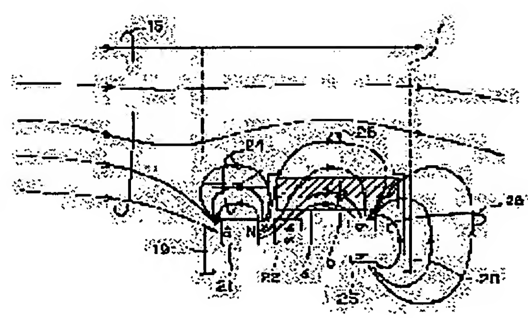
(54) THIN FILM FORMING DEVICE

(57)Abstract:
PURPOSE: To efficiently form a high-quality thin film by ECR sputtering by generating a magnetic field in the vertical direction, in the reverse direction and in the same direction to a plasma drawing divergent magnetic field on both ends and surface of a cylindrical target electrode, respectively.



CONSTITUTION: A microwave is introduced into the magnetic filed of an electromagnet, and the introduced gas is converted to plasma by electron cyclotron resonance(ECR). The plasma is drawn into a film forming device by a divergent magnetic field to sputter a cylindrical target surrounding the plasma current, and a thin film is formed on a substrate. In this thin film forming device, plural cylindrical permanent magnets 21 to 23 are arranged around the backing plate 13 of a cylindrical target electrode 7 provided with the cylindrical target 15 surrounding the divergent magnetic field 16. Consequently, a magnetic field is generated in the reverse direction to the divergent magnetic field 16 between the target 15 and a plasma drawing window (not shown in the figure), in the same direction on the target 15 and in the vertical direction on both ends of the target.

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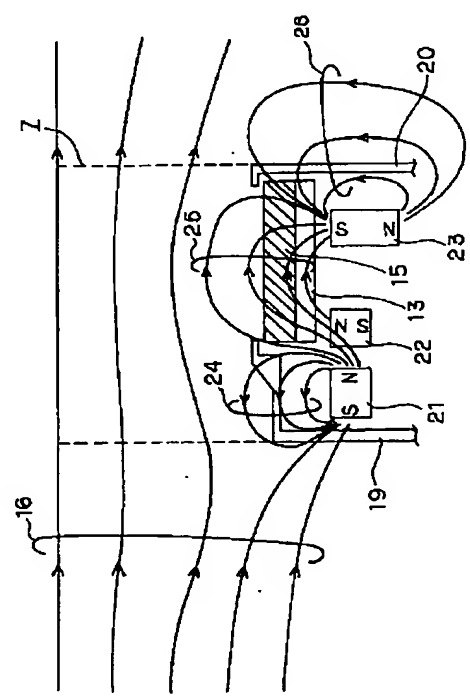
(54)【発明の名称】薄膜形成装置

(57)【要約】

【目的】　高品質薄膜を効率よく形成することができるＥＣＲスパッタによる薄膜形成装置を提供する。

【構成】　プラズマ生成室のプラズマ引出し窓から引き出されたプラズマ流を囲むように同軸状に配置されたターゲット電極のターゲットをスパッタすることにより成膜室中に設置した基板上に薄膜を形成する際に、前記ターゲット電極が、プラズマ室からの発散形磁界の軸方向磁界に対し、ターゲットとプラズマ引き出し窓の間では逆方向の所定の磁界を発生し、ターゲットの表面では同一方向の磁界を発生し、ターゲットのプラズマ引き出し窓側及びターゲットの成膜室側の両端部で垂直方向の磁界を発生するように永久磁石をターゲットと前記プラズマ引き出し窓の間及びターゲットの外周に配置した構成を有している。



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【特許請求の範囲】

【請求項１】　電磁石で発生した磁界の中にプラズマ生成室を備え、該プラズマ生成室にプラズマ用ガス及びマイクロ波が導入されて電子サイクロトン共鳴（ＥＣＲ）により該プラズマ生成室内にプラズマが生成され、前記電磁石で発生した発散形磁界により、前記プラズマ生成室のプラズマ引出し窓から前記プラズマを成膜室に引き出し、この引き出されたプラズマ流を囲むように同軸状に配置されたターゲット電極のターゲットをスパッタすることにより、前記成膜室中に設置した基板上に薄膜を形成するＥＣＲスパッタによる薄膜形成装置において、前記ターゲット電極が、前記ターゲットと前記プラズマ引き出し窓の間では前記発散形磁界の軸方向磁界と逆方向の所定の磁界を発生し、前記ターゲットの表面では発散形磁界の軸方向磁界と同一方向の磁界を発生し、前記ターゲットの前記プラズマ引き出し窓側及び該ターゲットの前記成膜室側の両端部で発散形磁界の軸方向に対して垂直方向の磁界を発生するための永久磁石を前記ターゲットと前記プラズマ引き出し窓の間及び前記ターゲットの外周に配置した構造であることを特徴とする薄膜形成装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、電子サイクロトロン共鳴（ＥＣＲ）により生成したプラズマを発散形磁界により引き出し、この引き出されたプラズマを利用して薄膜を形成する薄膜形成装置において、原料供給を固体ターゲットのスパッタで行うことにより高速で薄膜を形成するＥＣＲスパッタ装置に関する。

【０００２】

【従来の技術】従来のプレーナ型スパッタ装置で薄膜を形成する場合、形成中の薄膜は高エネルギー粒子の照射を受けるために大きな損傷を被る。このため基板をターゲットの側面に置くなど、高エネルギー粒子の影響を直接受けないような工夫がなされていた。しかし、このような方法には、薄膜の堆積速度が極端に遅くなる欠点があった。

【０００３】上記の通常のスパッタ法に対して、１０^{-2}～１０^{-1}Ｐａの低ガス圧中でスパッタするＥＣＲスパッタ法では、プラズマ中のイオンのエネルギーが２０～３０ｅＶと低エネルギーであるため、プラズマ照射による薄膜の損傷が極めて小さく、高品質薄膜を形成できる特徴がある。また、ＥＣＲプラズマは通常のスパッタにおいて生成したプラズマと比較して高活性であるため、反応スパッタでは薄膜形成を促進する効果がある。これらのことから、近年、ＥＣＲスパッタ法による薄膜形成が盛んに行われるようになった。

【０００４】基本的なＥＣＲスパッタ装置は、図１の断面図に示すように、プラズマ生成部（マイクロ波導波管１，マイクロ波導入窓２，電磁石３，円筒形のプラズマ生成室４等）、円筒形のターゲット電極７及び成膜室９などから構成されている。このような装置を用いて、薄膜形成は次のようにして行う。プラズマ生成室４にプラズマ用ガス及びマイクロ波を導入して、１０^{-2}～１０^{-1}Ｐａの低ガス圧中でＥＣＲプラズマを生成し、これを電磁石３で発生した発散形磁界によりプラズマ引き出し窓５からプラズマ生成室４の外の成膜室９に引き出す。このプラズマ流中のイオンの一部を利用して、ＥＣＲプラズマ流１０を囲むように配置されたターゲット電極７にある円筒形ターゲットをスパッタする。スパッタされた粒子及びＥＣＲプラズマは成膜室９の中に設置した基板１１上に供給され、薄膜を形成する。

【０００５】このようなＥＣＲスパッタ装置において、薄膜の形成速度を上げるために、ターゲット電極７をマグネトロン型及び電界ミラー型にした装置〔応用物理５８巻８号ｐ．１２１７（１９８９）〕などが開発された。これらの装置では、いずれもターゲットの表面でのプラズマ密度を高くしてスパッタ速度を上げ、薄膜の形成速度を速くしていた。

【０００６】マグネトロン型ＥＣＲスパッタ装置におけるターゲット電極には、従来、軟鉄を設けた構造の電極（特開昭６０－１１４５１８号）及びターゲットの外周に永久磁石を設けた構造の電極（特開平２－２６７２６４号）が用いられていた。

【０００７】軟鉄を設けた筒形ターゲット電極７の一部断面図を図２に示す。この図で１３はバッキングプレート、１４は軟鉄、１５はターゲット、１６は電磁石３が発生する発散形磁界の磁力線、１７は軟鉄１４を設けたことにより発生する局所磁界の磁力線である。局所磁界の磁力線１７は、軟鉄１４が設けられている位置で一度ターゲット１５の内部に入り、次にターゲット１５のプラズマ引き出し窓５側の端部で表面から出て、再びターゲット１５の成膜室９側の端部でターゲット１５の内部に戻る。磁力線１７がターゲット１５の表面に平行であるときには、発散形磁界の磁力線１６の向きと平行になるため、マグネトロン放電を起こすのに十分な磁界強度が得られる。このため、プラズマ流１０がターゲット１５の表面に供給されるとマグネトロン放電が起こり、薄膜の形成速度が速くなる。しかし、ターゲット１５の両端部において、発散形磁界の軸方向に対して垂直方向の磁界強度が不十分であるため、２次電子の閉じ込め効果が悪く、マグネトロン放電が起こるガスの圧力範囲が１×１０^{-1}Ｐａよりも高く、ＥＣＲプラズマを利用する効果が減少する。

【０００８】そこで、低ガス圧中でマグネトロン放電を起こすために、図３の断面図に示すような、円筒形ターゲット１５の外周に永久磁石１８を設けた構成のターゲット電極７が開発された。この電極では、ターゲット１５の表面における磁力線１８ａの向きが発散形磁界の磁力線の向きと逆方向であり、ターゲット１５の両端部に

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における垂直方向の磁界強度を強くしている。その結果、電子の閉じ込めが向上し、１０$^{-2}$Ｐａ台の低ガス圧中でマグネトロン放電が実現した。

【０００９】

【発明が解決しようとする課題】しかし、永久磁石１８が発生する磁界の影響により基板面における発散形磁界は狭くなり、基板上に供給されるＥＣＲプラズマは中心部に限られ、周辺部ではほとんど供給されない欠点があった。その上、ターゲット１５の表面における発散形磁界軸方向の磁界の強度分布が悪く、ターゲット１５の中心部だけが強くスパッタされことになる。このため、ターゲット１５の利用効率が低く最大でも３０％程度であるという欠点もあった。

【００１０】本発明は、上記のマグネトロン型ＥＣＲスパッタ装置の欠点を解決し、高品質薄膜を効率よく形成することができるＥＣＲスパッタによる薄膜形成装置を提供することを目的とする。

【００１１】

【課題を解決するための手段】この目的を達成するために、本発明の薄膜形成装置は、電磁石で発生した磁界の中にプラズマ生成室を備え、該プラズマ生成室にプラズマ用ガス及びマイクロ波が導入されて電子サイクロトン共鳴（ＥＣＲ）により該プラズマ生成室内にプラズマが生成され、前記電磁石で発生した発散形磁界により、前記プラズマ生成室のプラズマ引出し窓から前記プラズマを成膜室に引き出し、この引き出されたプラズマ流を囲むように同軸状に配置されたターゲット電極のターゲットをスパッタすることにより、前記成膜室中に設置した基板上に薄膜を形成するＥＣＲスパッタによる薄膜形成装置において、前記ターゲット電極が、前記ターゲットと前記プラズマ引き出し窓の間では前記発散形磁界の軸方向磁界と逆方向の所定の磁界を発生し、前記ターゲットの表面では発散形磁界の軸方向磁界と同一方向の磁界を発生し、前記ターゲットの前記プラズマ引き出し窓側及び該ターゲットの前記成膜室側の両端部で発散形磁界の軸方向に対して垂直方向の磁界を発生するための永久磁石を前記ターゲットと前記プラズマ引き出し窓の間及び前記ターゲットの外周に配置した構造であることを特徴とする構成を有している。以下本発明装置の構成及び機能について具体的に説明する。

【００１２】本発明のマグネトロン型ＥＣＲスパッタ装置は、図１に示した基本的なＥＣＲスパッタ装置と同様に、ＥＣＲプラズマ発生部（１，２，３，４），筒形（例えば円筒形）ターゲット電極７及び成膜室９から構成されている。プラズマ生成室４におけるＥＣＲプラズマの発生及び発散形磁界によるプラズマの引き出しは前記の基本的装置の場合と同様に行われる。ターゲット電極７は、プラズマ引き出し窓５に隣接して、プラズマ流を囲むように同軸状に配置される。このターゲット電極７には後述のようにターゲットとプラズマ引き出し窓の間及びターゲットの外周に永久磁石が配置されるため、ターゲットとプラズマ引き出し窓の間で発散形磁界の軸方向磁界と逆方向の磁界を発生し、ターゲットの表面で発散形磁界の軸方向磁界と同一方向の磁界を発生し、ターゲットのプラズマ引き出し窓側及びターゲットの成膜室側の両端部で発散形磁界の軸方向に対して垂直方向の磁界を発生する。

【００１３】このようにして発生した局所磁界では磁力線がターゲットの両端部で強く集中するため、発散形磁界の軸方向に垂直な方向の磁界強度が１００Ｇ以上の強さになる。このため電子の閉じ込め効果が高く、５×１０$^{-2}$Ｐａまでの低ガス圧で安定にマグネトロン放電が起こり、効率よくスパッタすることができる。上記の各局所磁界はターゲット近傍に集中して、基板面における発散形磁界の狭小化に及ぼす影響が小さいので、ＥＣＲプラズマの基板への供給を損なわずに薄膜形成を行うことができる効果がある。さらに、上記のターゲット表面における発散形磁界の軸方向の磁界強度の均一性が向上するので、ターゲットの全面にわたってスパッタされ、ターゲットの利用効率が向上する効果がある。

【００１４】上記のような局所磁界を発生するために、ターゲットとプラズマ引き出し窓との間に配置される円筒形永久磁石の数及びターゲットの外周に配置される円筒形永久磁石の数は特に限定されない。ターゲットの利用効率の向上のためには、ターゲットの外周に配置される永久磁石は複数個配置することが好ましい。

【００１５】

【実施例】図４は、本発明の実施例である円筒形マグネトロン型ターゲット電極の断面図である。ここで、１３は銅製のバッキングプレート、１５はターゲット、１６は発散形磁界の磁力線、１９及び２０はそれぞれプラズマ引き出し窓５側のターゲットシールド板及び成膜室側のターゲットシールド板、２１は円筒形の第１の永久磁石、２２は円筒形の第２の永久磁石、２３は円筒形の第３の永久磁石、２４，２５及び２６は３個の永久磁石を設けたことにより発生した局所磁界の磁力線である。

【００１６】ここで、ターゲット１５は１００mmφ×１１０mmφ×５０mmの円筒であり、前記のプラズマ流を囲むように同軸状に配置した。プラズマ引き出し窓５側のターゲットシールド板１９の端と成膜室側のターゲットシールド板２０の端との間の距離、即ちスパッタされるターゲット部分の長さは４０mmとした。各永久磁石２１，２２，２３は長方形の永久磁石を張り合わせて製造した。発散形磁界の軸方向は、プラズマ引き出し窓５から成膜室に向かうように調節した。

【００１７】第１の永久磁石２１は、ターゲット１５とプラズマ引き出し窓５の間で、ターゲット１５に対して同軸状に配置した。この磁石のＮ極－Ｓ極の方向は発散形磁界の軸方向と平行にするとともに、Ｓ極をプラズマ引き出し窓５側に向けた。第２の永久磁石２２はターゲ

ット１５のプラズマ引き出し窓５側の外周に同軸状に配置し、N極－S極の方向をターゲット１５の表面に対して垂直にするとともに、N極をターゲット１５側に向けた。第３の永久磁石２３は第２の永久磁石２２の位置よりも成膜室９側に配置し、N極－S極の方向をターゲット１５の表面に対して垂直にするとともに、S極をターゲット１５側に向けた。

【００１８】このような３個の永久磁石の配置により、磁力線２４で示すように、ターゲット１５の表面からプラズマ引き出し窓５側に延長した表面において、発散形磁界の軸方向と逆向きの磁界が発生し、磁力線２５で示すように、ターゲット１５の表面では発散形磁界の軸方向と同じ方向の磁界が発生し、ターゲットシールド板１９のプラズマ引き出し窓側の端部及びターゲットシールド板２０の成膜室側の端部において発散形磁界の軸方向に垂直の方向の磁界を発生させた。

【００１９】上記の各局所磁界の強度は、それぞれターゲット１５の表面上の発散形磁界の軸方向と同じ方向では７７０G、各ターゲットシールド板１９，２０の端における発散形磁界の軸方向と同じ方向ではゼロに近く、各ターゲット用シールド板１９，２０の端におけるターゲット１５の表面に垂直な方向では１３０G以上であった。このように、本発明の磁界はターゲットシールド板１９，２０の両端部、即ちターゲット１５の両端部に相当する部分に集中することを確認した。

【００２０】上記の実施例の特性例として、ターゲット１５として絶縁性の円筒形Ｓｉターゲットを用い、プラズマ生成室にＡｒガス及び４００Wのマイクロ波電力を導入してECRプラズマを生成するとともに、ターゲット電極７に５００Wの高周波電力を投入してスパッタを行ったときの、高周波電力のｐｅａｋ－ｔｏ－ｐｅａｋ電圧（Ｖｐｐ）とＡｒガス圧の関係を図５に示す。この図から、4×10^{-2}Ｐａ以上のガス圧中でのＶｐｐは約５００Ｖで一定であり、それよりも低ガス圧で急に高くなることがわかる。この結果から、4×10^{-2}Ｐａ以上のガス圧でマグネトロン放電が起きることを確認した。

【００２１】次に、上記のスパッタ条件の中でＡｒガス圧を０．０６Ｐａとし、高周波電力を変えた場合のＶｐｐと高周波電力の関係を図６の黒丸印で示す。この図には、参考例として、ターゲット電極に永久磁石を配置しない場合についても白丸印で記載してある。この図から本発明の装置では、マグネトロン放電を起こすことにより、高周波電力が低く、高周波電力が大きくなっても高周波電圧の上昇割合が少ないことがわかる。このことは、投入した高周波電力が大きくなるとともに高周波電流が増加することを表しており、高周波電力の大部分がスパッタに有効に用いられていることを示している。一方、基板の位置に負のバイアス電圧を印加して、基板直上でのイオン電流を測定したところ、本発明のターゲット電極を用いた場合のイオン電流は、永久磁石を配置していないターゲット電極を用いたときのイオン電流よりも１０％程度減少するだけであった。このことから、広い面積のECRプラズマが基板に供給されることを確認した。以上の結果から本発明の装置により、基板へのECRプラズマの供給を大きく損なわずに、効率よくスパッタできることを確認した。

【００２２】次に、上記実施例の装置により、Ｚｎターゲットを用い、O_2 とＡｒの混合ガス中の反応スパッタによりガラス基板上にＺｎＯ薄膜を形成した。数１０回薄膜を形成した後のターゲットにおける発散形磁界の軸方向と平行な方向のエロージョンの断面図を図７に示す。この図では、ターゲットの上下左右の４箇所について測定した結果を示してある。この図からターゲットは全面にわたってスパッタされていることがわかる。ターゲットの利用効率は約６０％であり、図３で示した従来のマグネトロン型電極における利用効率（最大約３０％）よりも高いことを確認した。

【００２３】発散形磁界の軸方向磁界を図４における方向と逆にした場合には、各永久磁石のN極－S極の方向をすべて逆にすることにより、上記と同様の局所磁界分布が得られた。ターゲット電極に配置される永久磁石の数及びN極－S極の方向は図４に示された組合せに限定されるものではなく、幾つかの組合せにより、上記と同様の局所磁界を発生することが可能である。

【００２４】

【発明の効果】以上説明したように、本発明のECRスパッタ装置では、10^{-2}Ｐａの低ガス圧中で安定にマグネトロン放電が起こり、発生したECRプラズマの多くが基板に供給されるので、高品質薄膜を高速で形成することが可能であり、さらに、スパッタはターゲットの全面で起こるのでターゲットの利用効率が高い効果がある。

【図面の簡単な説明】

【図１】基本的なECRスパッタ装置の断面図である。

【図２】図１におけるECRスパッタ装置の円筒形ターゲット電極において、軟鉄を設けた構成の、従来のマグネトロン型ターゲット電極の断面図である。

【図３】図１におけるECRスパッタ装置の円筒形ターゲット電極において、ターゲットの外周に永久磁石を設けた構成の、従来のマグネトロン型ターゲット電極の断面図である。

【図４】本発明の実施例であるECRスパッタ装置における円筒形のマグネトロン型ターゲット電極の断面図である。

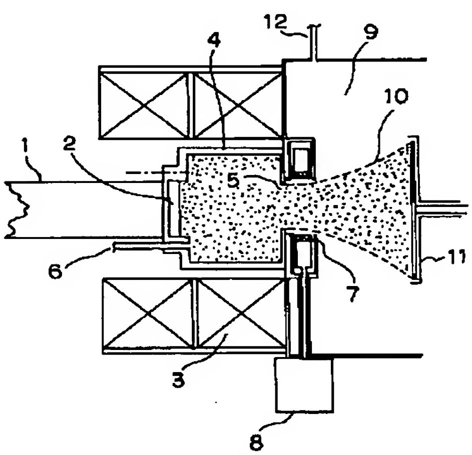
【図５】本発明のECRスパッタ装置において、絶縁性のＳｉターゲットを用い、Ａｒガス及び４００Wのマイクロ波電力を導入してECRプラズマを生成し、５００Wの高周波電力をターゲットに投入した場合の、高周波電力のｐｅａｋ－ｔｏ－ｐｅａｋ電圧（Ｖｐｐ）とガス圧の関係を示した特性図である。

【図６】本発明のＥＣＲスパッタ装置において、絶縁性のＳｉターゲットを用い、Ａｒガス圧を０．０６Ｐａとし、４００Ｗのマイクロ波電力を導入してＥＣＲプラズマを生成した場合の、Ｖｐｐと高周波電力の関係を示す特性図（黒丸印）、及びこれと同じスパッタ条件でターゲット電極の中に永久磁石が無い場合の参考図（白丸印）である。
【図７】本発明のＥＣＲスパッタ装置において、Ｚｎターゲットを用い、O_2 とＡｒの混合ガス中で反応スパッタを行い、数１０回薄膜を形成した後の、発散形磁界の軸方向の、ターゲットのエロージョンを示す図である。

【符号の説明】

１　マイクロ波導波管
２　マイクロ波導入窓
３　電磁石
４　プラズマ生成室
５　円筒形のプラズマ引き出し窓
６　ガス導入口
７　円筒形のターゲット電極
８　スパッタ用電源
９　成膜室
１０　プラズマ流
１１　基板
１２　成膜室へのガス導入口
１３　円筒形のバッキングプレート
１４　円筒形の軟鉄
１５　円筒形のターゲット
１６　発散形磁界の磁力線
１７　軟鉄１４が発生する局所磁界の磁力線
１８　永久磁石
１８ａ　永久磁石１８が発生する局所磁界
１９　プラズマ引き出し窓側のターゲットシールド板
２０　成膜室側のターゲットシールド板
２１　円筒形の第１の永久磁石
２２　円筒形の第２の永久磁石
２３　円筒形の第３の永久磁石
２４，２５，２６　第１の永久磁石２１、第２の永久磁石２２及び第３の永久磁石２３が一組となって発生する局所磁界の磁力線。

【図１】



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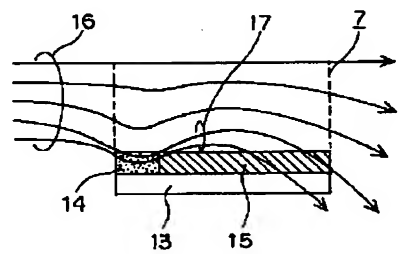

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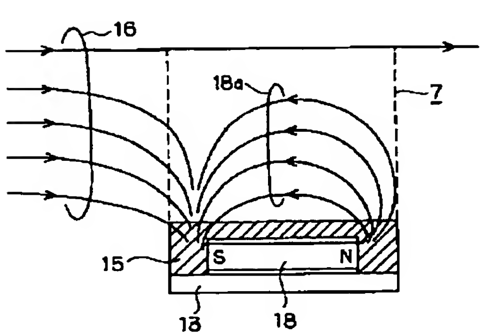
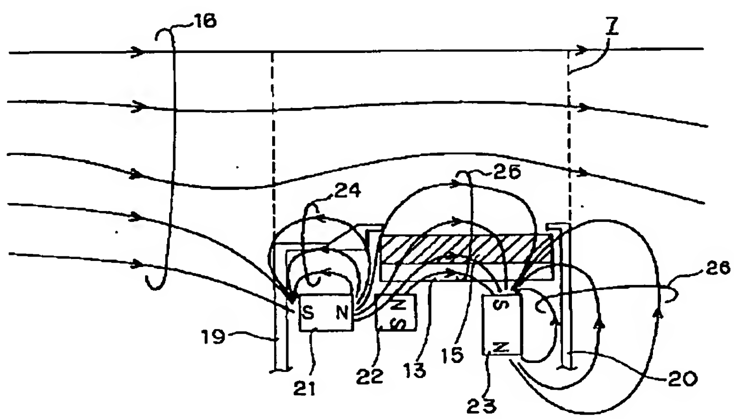


【図４】



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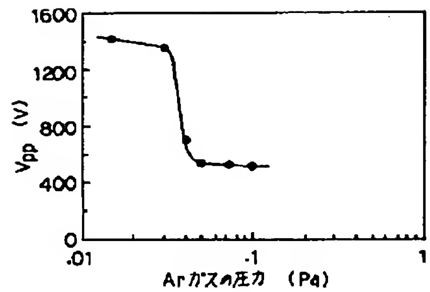

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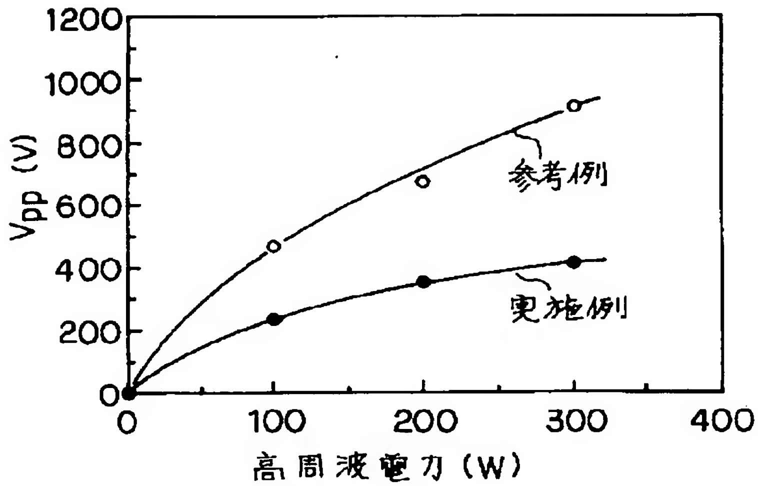

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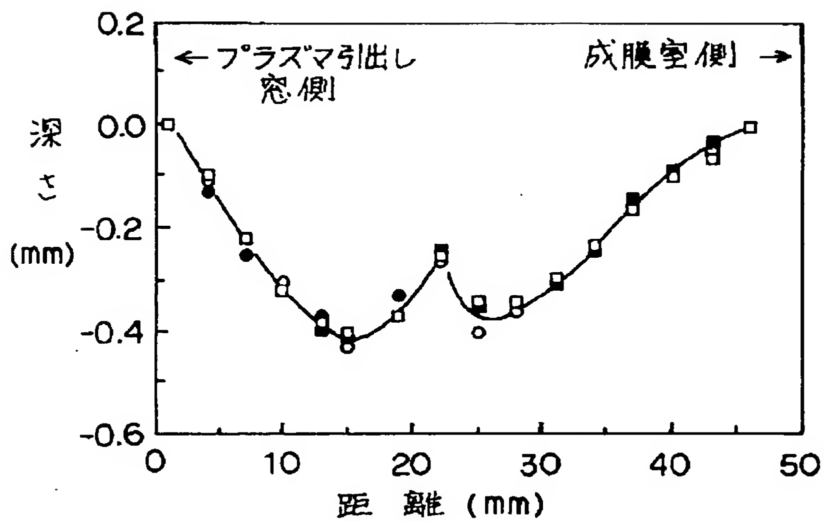

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[Translation done.]

Epitome

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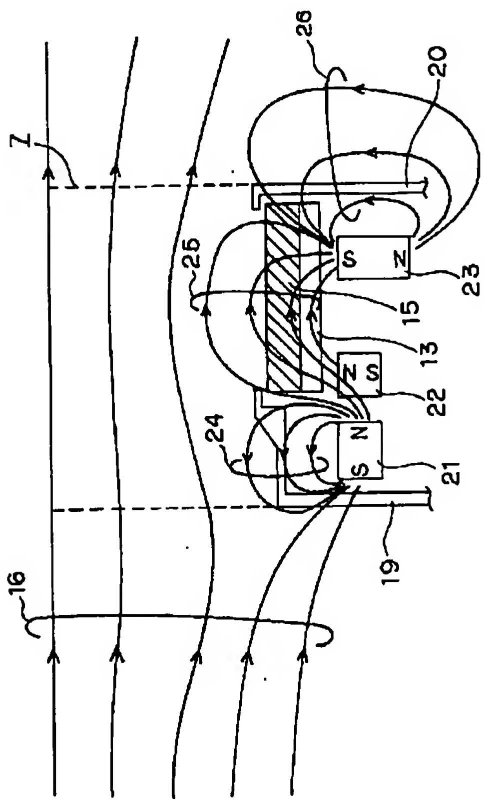
(57) [Abstract]
[Objects of the Invention] The thin film deposition system by the ECR spatter which can form a high quality thin film efficiently is offered.
[Elements of the Invention] In case a thin film is formed on the substrate installed all over the membrane formation room by carrying out the spatter of the target of the target electrode arranged in the shape of the same axle so that the plasma style pulled out from the plasma cash-drawer aperture of a plasma production room may be surrounded Said target electrode receives the shaft-orientations field of the emission form field from a plasma room. The predetermined field of hard flow is generated between a target and a plasma drawer aperture. It has the configuration which has arranged the permanent magnet between a target

and said plasma drawer apertures and on the periphery of a target so that the field of the same direction may be generated on the surface of a target and a vertical field may be generated at the both ends by the side of the plasma drawer aperture of a target, and the membrane formation room of a target.

[Translation done.]



[Translation done.]

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1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
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CLAIMS

[Claim(s)]
[Claim 1] Have a plasma production room into the field generated with the electromagnet, the gas for plasma and microwave are introduced into this plasma production room, and the plasma is generated by this plasma production interior of a room by electronic SAIKU roton resonance (ECR). The emission form field generated with said electromagnet draws out said plasma in a membrane formation room from the plasma cash-drawer aperture of said plasma production room. By carrying out the spatter of the target of the target electrode arranged in the shape of the same axle so that this pulled-out plasma style may be surrounded In the thin film deposition system by the ECR spatter which forms a thin film on the substrate installed all over said membrane formation room Said target electrode generates the shaft-orientations field of said emission form field, and the predetermined field of hard flow between said target and said plasma drawer aperture. On the front face of said target, the field of the same direction as the shaft-orientations field of an emission form field is generated. The shaft orientations of an emission form field are received at the both ends by the side of said plasma drawer aperture of said target, and said membrane formation room of this target. The thin film deposition system characterized by being the structure which has arranged the permanent magnet for generating a vertical field between said target and said plasma drawer apertures and on the periphery of said target.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention pulls out the plasma generated by the electron cyclotron resonance (ECR) by the emission form field, and relates to the ECR sputtering system which forms a thin film at high speed by performing feeding by the spatter of a solid-state target in the thin film deposition system which forms a thin film using this pulled-out plasma.
[0002]
[Description of the Prior Art] When forming a thin film with the conventional BURENA mold sputtering system, big damage is received in order that the thin film under formation may receive the exposure of a high energy particle. For this reason, a device which does not have a direct receptacle was made in the effect of a high energy particle, such as putting a substrate on the side face of a target. However, such an approach had the fault to which the rate of sedimentation of a thin film becomes extremely slow.
[0003] In the ECR spatter which carries out a spatter to the above-mentioned usual spatter in the low gas pressure of 10-2 to ten to 1 Pa, since the energy of the ion in the plasma is 20-30eV and low energy, damage on the thin film by plasma exposure is very small, and there is the description which can form a high quality thin film. Moreover, since the ECR plasma is high activity as compared with the plasma generated in the usual spatter, it has the effectiveness which promotes thin film formation in reactive sputtering. From these things, thin film formation by the ECR spatter came to be performed briskly in recent years.
[0004] The fundamental ECR sputtering system consists of target electrodes 7, the membrane formation rooms 9, etc. of the plasma production section (a microwave waveguide 1, the microwave installation aperture 2, an electromagnet 3, plasma production room 4 grade of a cylindrical shape), and a cylindrical shape, as shown in the sectional view of drawing 1 . Thin film formation is performed as follows using such equipment. The gas for plasma and microwave are introduced into the plasma production room 4, the ECR plasma is generated in the low gas pressure of 10-2 to ten to 1 Pa, and the emission form field generated with the electromagnet 3 draws this out in the membrane formation room 9 outside the plasma production room 4 from the plasma drawer aperture 5. The spatter of the cylindrical shape target in the target electrode 7 arranged so that the ECR plasma style 10 may be surrounded is carried out using some ion in this plasma style. The particle and ECR plasma by which the spatter was carried out are supplied on the substrate 11

installed into the membrane formation room 9, and form a thin film.
[0005] In such an ECR sputtering system, in order to gather the formation rate of a thin film, the equipment [application physics 58 volume 8 No. p.1217 (1989)] which used the target electrode 7 as the magnetron mold and the electric-field mirror mold was developed. With these equipments, each made high the plasma consistency in the front face of a target, the sputtering rate was gathered and the formation rate of a thin film was made quick.
[0006] The electrode (JP,2-267264,A) of the structure which prepared the permanent magnet in the electrode (JP,60-114518,A) of the structure which prepared soft iron, and the periphery of a target was conventionally used for the target electrode in a magnetron mold ECR sputtering system.
[0007] some cartridge target electrodes 7 which prepared soft iron -- a sectional view is shown in drawing 2 . The line of magnetic force of an emission form field with which in 13 a target generates soft iron and 15 and, as for the back up plate and 14, an electromagnet 3 generates 16 in this drawing, and 17 are line of magnetic force of a partial field generated by having formed soft iron 14. The line of magnetic force 17 of a partial field goes into the interior of a target 15 in the location in which soft iron 14 is formed once, then, comes out from a front face at the edge by the side of the plasma drawer aperture 5 of a target 15, and returns to the interior of a target 15 again at the edge by the side of the membrane formation room 9 of a target 15. Since it becomes the sense of the line of magnetic force 16 of an emission form field, and parallel when line of magnetic force 17 is parallel to the front face of a target 15, sufficient magnetic field strength to cause magnetron discharge is obtained. For this reason, if the plasma style 10 is supplied to the front face of a target 15, magnetron discharge will happen and the formation rate of a thin film will become quick. However, in the both ends of a target 15, to the shaft orientations of an emission form field, since vertical magnetic field strength is inadequate, the locked-in effect of a secondary electron is bad, the pressure range of the gas by which magnetron discharge happens is higher than 1x10 to 1 Pa, and the effectiveness of using the ECR plasma decreases.
[0008] Then, in order to cause magnetron discharge in low gas pressure, the target electrode 7 of a configuration of having formed the permanent magnet 18 in the periphery of the cylindrical shape target 15 as shown in the sectional view of drawing 3 was developed. In this electrode, the sense of line-of-magnetic-force 18a in the front face of a target 15 is

the sense and hard flow of line of magnetic force of an emission form field, and magnetic field strength of the perpendicular direction in the both ends of a target 15 is strengthened. Consequently, the electron closed, eye ** improved and magnetron discharge was realized in the low gas pressure of a 10-2Pa base.

[0009]

[Problem(s) to be Solved by the Invention] However, the emission form field in a substrate side became narrow under the effect of the field which a permanent magnet 18 generates, and the ECR plasma supplied on a substrate was restricted to the core, and had the fault hardly supplied in the periphery. Moreover, it is bad, and the spatter only of the core of a target 15 is carried out strongly, and the intensity distribution of the field of the emission form field shaft orientations in the front face of a target 15 become things. For this reason, the fault that it was about 30% at the maximum low also had the use effectiveness of a target 15.

[0010] This invention solves the fault of the above-mentioned magnetron mold ECR sputtering system, and aims at offering the thin film deposition system by the ECR spatter which can form a high quality thin film efficiently.

[0011]

[Means for Solving the Problem] In order to attain this purpose, the thin film deposition system of this invention Have a plasma production room into the field generated with the electromagnet, the gas for plasma and microwave are introduced into this plasma production room, and the plasma is generated by this plasma production interior of a room by electronic SAIKU roton resonance (ECR). The emission form field generated with said electromagnet draws out said plasma in a membrane formation room from the plasma cash-drawer aperture of said plasma production room. By carrying out the spatter of the target of the target electrode arranged in the shape of the same axle so that this pulled-out plasma style may be surrounded In the thin film deposition system by the ECR spatter which forms a thin film on the substrate installed all over said membrane formation room Said target electrode generates the shaft-orientations field of said emission form field, and the predetermined field of hard flow between said target and said plasma drawer aperture. On the front face of said target, the field of the same direction as the shaft-orientations field of an emission form field is generated. The shaft orientations of an emission form field are received at the both ends by the side of said plasma drawer aperture of said target, and said membrane formation room of this target. It has the configuration

characterized by being the structure which has arranged the permanent magnet for generating a vertical field between said target and said plasma drawer apertures and on the periphery of said target. The configuration and function of this invention equipment are explained concretely below.

[0012] The magnetron mold ECR sputtering system of this invention consists of the ECR plasma generating section (1, 2, 3, 4), a cartridge (for example, cylindrical shape) target electrode 7, and a membrane formation room 9 like the fundamental ECR sputtering system shown in drawing 1 . The drawer of the plasma by generating of the ECR plasma and the emission form field in the plasma production room 4 is performed like the case of above fundamental equipment. A target electrode 7 adjoins the plasma drawer aperture 5, and it is arranged in the shape of the same axle so that a plasma style may be surrounded. Since a permanent magnet is arranged like [this target electrode 7] the after-mentioned between a target and plasma drawer apertures and at the periphery of a target, the shaft-orientations field of an emission form field and the field of hard flow are generated between a target and a plasma drawer aperture, the field of the same direction as the shaft-orientations field of an emission form field is generated on the surface of a target, and a vertical field is generated to the shaft orientations of an emission form field at the both ends by the side of the plasma drawer aperture of a target, and the membrane formation room of a target.

[0013] Thus, in the generated partial field, in order that line of magnetic force may focus strongly at the both ends of a target, the magnetic field strength of a direction perpendicular to the shaft orientations of an emission form field becomes the strength beyond 100G. For this reason, an electronic locked-in effect is high, with the low gas pressure to 5x10 to 2 Pa, magnetron discharge happens to stability and a spatter can be efficiently carried out to it. Each above-mentioned partial field is concentrated near the target, and since the effect affect narrow-ization of the emission form field in a substrate side is small, it is effective in the ability to perform thin film formation, without spoiling supply to the substrate of the ECR plasma. Furthermore, since the homogeneity of the magnetic field strength of the shaft orientations of the emission form field in the above-mentioned target front face improves, a spatter is carried out over the whole surface of a target, and it is effective in the use effectiveness of a target improving.

[0014] Since the above partial fields are generated, especially the number of the cylindrical shape permanent magnets arranged at the number

of the cylindrical shape permanent magnets arranged between a target and a plasma drawer aperture and the periphery of a target is not limited. As for the permanent magnet arranged at the periphery of a target, for improvement in the use effectiveness of a target, it is desirable to arrange more than one.

[0015]

[Example] Drawing 4 is the sectional view of the cylindrical shape magnetron mold target electrode which is the example of this invention. Here, it is the line of magnetic force of a partial field which 13 generated the copper back up plate and 15 with the target, and generated 16 when the 2nd permanent magnet of a cylindrical shape and 23 prepared the 3rd permanent magnet of a cylindrical shape and, as for 24, 25, and 26, the 1st permanent magnet of a cylindrical shape and 22 prepared [the line of magnetic force of an emission form field, and 19 and 20] three permanent magnets in the target shielding plate by the side of the plasma drawer aperture 5 and the target shielding plate by the side of a membrane formation room, and 21, respectively.

[0016] Here, a target 15 is a 100mm phix110mm phix50mm cylinder, and it has been arranged in the shape of the same axle so that the aforementioned plasma style may be surrounded. The distance between the edge of the target shielding plate 19 by the side of the plasma drawer aperture 5 and the edge of the target shielding plate 20 by the side of a membrane formation room, i.e., the die length of a target part by which a spatter is carried out, was set to 40mm. Each permanent magnets 21, 22, and 23 made the rectangular permanent magnet rival, and were manufactured. The shaft orientations of an emission form field were adjusted so that it might go to a membrane formation room from the plasma drawer aperture 5.

[0017] The 1st permanent magnet 21 has been arranged in the shape of the same axle to a target 15 between a target 15 and the plasma drawer aperture 5. The direction of the N pole-south pole of this magnet turned the south pole to the plasma drawer aperture 5 side while making it into the shaft orientations of an emission form field at parallel. N pole was turned to the target 15 side, while having arranged the 2nd permanent magnet 22 in the shape of the same axle on the periphery by the side of the plasma drawer aperture 5 of a target 15 and making the direction of the N pole-south pole perpendicular to the front face of a target 15. The 3rd permanent magnet 23 turned the south pole to the target 15 side while it has arranged to the membrane formation room 9 side and made the direction of the N pole-south pole more nearly perpendicular than the location of the 2nd permanent magnet 22 to the front face of a target 15.

[0018] By arrangement of such three permanent magnets, as line of magnetic force 24 shows In the front face extended from the front face of a target 15 to the plasma drawer aperture 5 side As the shaft orientations of an emission form field and the field of the reverse sense occur and line of magnetic force 25 shows On the front face of a target 15, the field of the same direction as the shaft orientations of an emission form field occurred, and the field of a direction perpendicular to the shaft orientations of an emission form field was generated in the edge by the side of the plasma drawer aperture of the target shielding plate 19, and the edge by the side of the membrane formation room of the target shielding plate 20.

[0019] The reinforcement of each above-mentioned partial field was more than 130G in the direction respectively perpendicular to the front face of the target [in / to zero / the edge of near and each shielding plates 19 and 20 for targets] 15 in the same direction as the shaft orientations of the emission form field on the front face of a target 15, and the shaft orientations of an emission form field [in / in the same direction / the edge of 770G and each target shielding plates 19 and 20]. Thus, it checked concentrating the field of this invention on the part equivalent to the both ends of the target shielding plates 19 and 20, i.e., the both ends of a target 15.

[0020] While introducing Ar gas and the microwave power of 400W into a plasma production room and generating the ECR plasma as an example of a property of the above-mentioned example using an insulating cylindrical shape Si target as a target 15, the relation between the peak-to-peak electrical potential difference (Vpp) of high-frequency power when supplying the high-frequency power of 500W to a target electrode 7, and performing a spatter and Ar gas pressure is shown in drawing 5 . Vpp in the inside of the gas pressure of 4x10 - 2 or more Pa is fixed at about 500 V, and this drawing shows becoming high suddenly with low gas pressure rather than it. From this result, it checked that magnetron discharge broke out with the gas pressure of 4x10 - 2 or more Pa.

[0021] Next, Ar gas pressure is set to 0.06Pa in the above-mentioned spatter conditions, and the black dot mark of drawing 6 shows Vpp at the time of changing high-frequency power, and the relation of high-frequency power. In this drawing, the case where a permanent magnet is not arranged to a target electrode is also indicated by the white round mark as an example of reference. By starting magnetron discharge from this drawing with the equipment of this invention shows that there are few rise rates of high-frequency voltage, even if high-frequency power is low and high-frequency power becomes large. This means that the high

frequency current increases while the switched-on high-frequency power becomes large, and it shows that the great portion of high-frequency power is used effective in a spatter. On the other hand, when negative bias voltage was impressed to the location of a substrate and the ion current of substrate right above was measured, the ion current at the time of using the target electrode of this invention only decreased about 10% rather than the ion current when using the target electrode which does not arrange the permanent magnet. It checked that the ECR plasma of a large area was supplied to a substrate from this. With the equipment of this invention, it checked that a spatter could be carried out efficiently from the above result, without spoiling supply of the ECR plasma to a substrate greatly.

[0022] Next, Zn target is used with the equipment of the above-mentioned example, and it is O2. The ZnO thin film was formed on the glass substrate by the reactive sputtering in the mixed gas of Ar. The sectional view of the erosion of a direction parallel to the shaft orientations of the emission form field in the target after forming a thin film several 10 times is shown in drawing 7 . This drawing has shown the result measured about four places of the four directions of a target. This drawing shows that the spatter of the target is carried out over the whole surface. The use effectiveness of a target is about 60%, and it checked that it was higher than the use effectiveness (about 30% of maxes) in the conventional magnetron mold electrode shown by drawing 3 .

[0023] When the shaft-orientations field of an emission form field was made into the direction and reverse in drawing 4 , the same partial field distribution as the above was acquired by making all the directions of the N pole-south pole of each permanent magnet into reverse. It is not limited to the combination shown in drawing 4 , and the number of the permanent magnets arranged at a target electrode and the direction of the N pole-south pole can generate the same partial field as the above with some combination.

[0024]

[Effect of the Invention] As explained above, with the ECR sputtering system of this invention, it is possible to form a high quality thin film at high speed, since magnetron discharge happens to stability in the low gas pressure of ten to 2 Pa and many of generated ECR plasma is supplied to a substrate, and since a spatter happens all over a target, it has further the effectiveness that the use effectiveness of a target is high.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the sectional view of a fundamental ECR sputtering system.
[Drawing 2] In the cylindrical shape target electrode of the ECR sputtering system in drawing 1 , it is the sectional view of the conventional magnetron mold target electrode of a configuration of having prepared soft iron.
[Drawing 3] In the cylindrical shape target electrode of the ECR sputtering system in drawing 1 , it is the sectional view of the conventional magnetron mold target electrode of a configuration of having prepared the permanent magnet in the periphery of a target.
[Drawing 4] It is the sectional view of the magnetron mold target electrode of the cylindrical shape in the ECR sputtering system which is the example of this invention.
[Drawing 5] In the ECR sputtering system of this invention, it is the property Fig. having shown the relation between the peak-to-peak electrical potential difference (Vpp) of high-frequency power at the time of introducing Ar gas and the microwave power of 400W, generating the ECR plasma using insulating Si target, and supplying the high-frequency power of 500W to a target, and gas pressure.
[Drawing 6] In the ECR sputtering system of this invention, it is a reference drawing (white round mark) in case there is no permanent magnet into a target electrode on the property Fig. (black dot mark) showing the relation of the Vpp and high-frequency power at the time of setting Ar gas pressure to 0.06Pa, introducing the microwave power of 400W using insulating Si target, and generating the ECR plasma, and the same spatter conditions as this.

[Drawing 7] Zn target is used in the ECR sputtering system of this invention, and it is 02. It is drawing showing the erosion of a target of the shaft orientations of an emission form field after performing reactive sputtering in the mixed gas of Ar and forming a thin film several 10 times.

[Description of Notations]

1 Microwave Waveguide
2 Microwave Installation Aperture
3 Electromagnet
4 Plasma Production Room
5 Plasma Drawer Aperture of Cylindrical Shape
6 Gas Inlet
7 Target Electrode of Cylindrical Shape
8 Power Source for Spatters
9 Membrane Formation Room
10 Plasma Style
11 Substrate
12 Gas Inlet to Membrane Formation Room
13 Back Up Plate of Cylindrical Shape
14 Soft Iron of Cylindrical Shape
15 Target of Cylindrical Shape
16 Line of Magnetic Force of Emission Form Field
17 Line of Magnetic Force of Partial Field Which Soft Iron 14 Generates
18 Permanent Magnet
18a The partial field which a permanent magnet 18 generates
19 Target Shielding Plate by the side of Plasma Drawer Aperture
20 Target Shielding Plate by the side of Membrane Formation Room
21 1st Permanent Magnet of Cylindrical Shape
22 2nd Permanent Magnet of Cylindrical Shape
23 3rd Permanent Magnet of Cylindrical Shape
24, 25, 26 Line of magnetic force of the partial field which the 1st permanent magnet 21, 2nd permanent magnet 22, and 3rd permanent magnet 23 serve as a lot, and generate.

[Translation done.]

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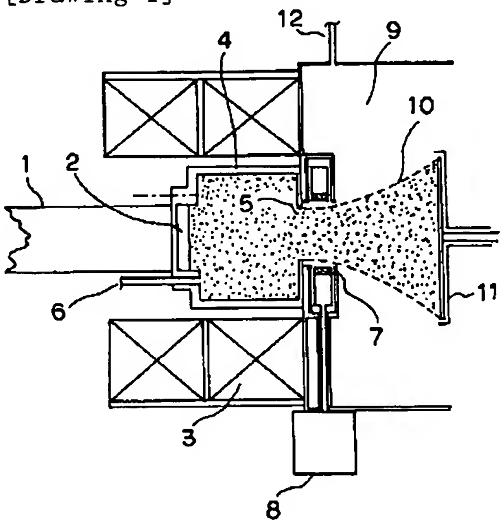
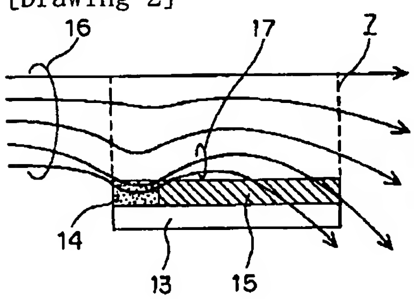
DRAWINGS

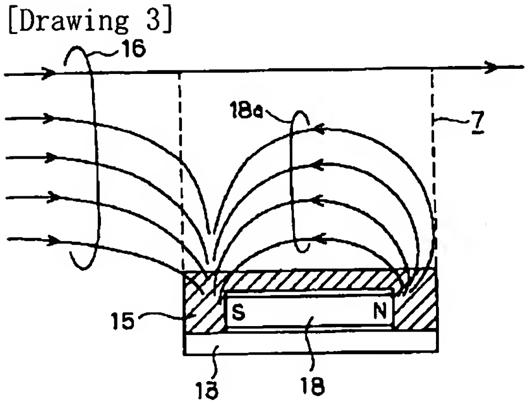
[Drawing 1]



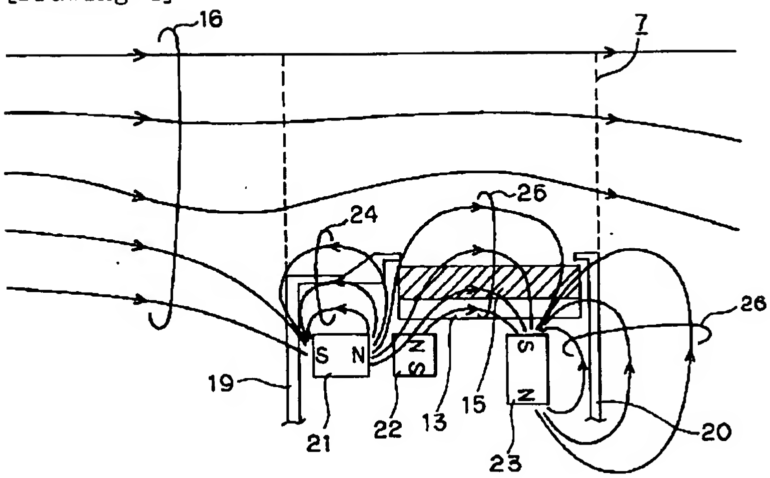
[Drawing 2]



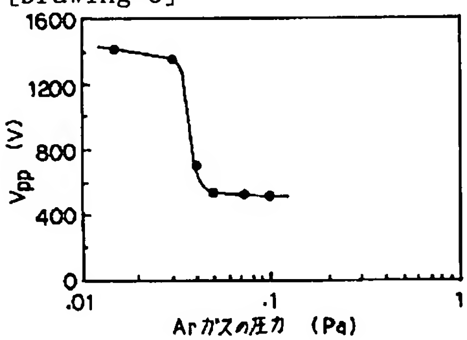
[Drawing 3]



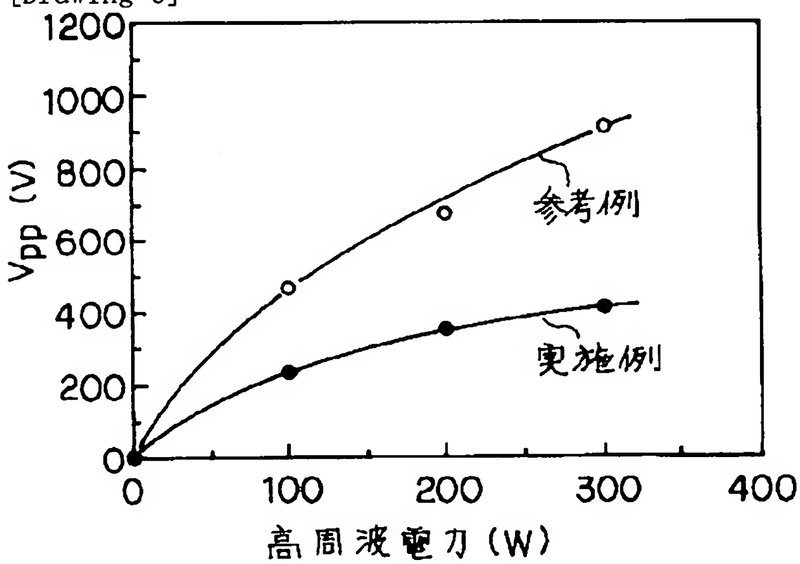
[Drawing 4]



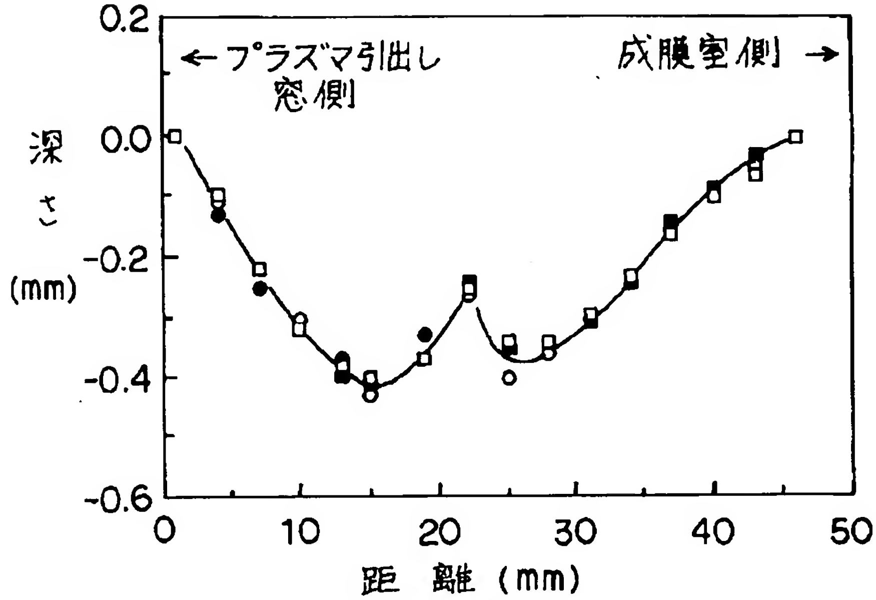
[Drawing 5]



[Drawing 6]



[Drawing 7]



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